WATER & LIFE

Diederik Rousseau (PhD, MSc)

Online Module on Water Quality Assessment
CONTENTS

1. Water, an extraordinary molecule
2. Water, a multitude of appearances
3. Water, omnipresent but scarce
4. Water, a host of life
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1. Water, an extraordinary molecule
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Lack of water

Too much water

Enjoying water

Enjoying water
Water molecules and aggregate formation

Water molecules are strong dipoles owing to spatial arrangements of atoms. Without pronounced dipole character water would not be liquid!

Electrostatic attraction of 2 molecules leads to hydrogen bridge formation

Water remains liquid at normal temperatures despite its low molecular weight. In normal ice a rigid crystalline structure is formed.

[Diagram showing water molecule structure and hydrogen bond formation]

Water molecule diagram:

- Oxygen (O) atom
- Hydrogen (H) atoms

Bond angles:
- O-H-O: 104.5°
- O-H: 109.47°

Bond lengths:
- O-H: 0.96 Å
- O-O: 1.86 Å

Electron pair: 

\[ +\delta \quad \text{O} \quad -2\delta \quad \text{H} \quad +\delta \]
Density of water

More DISSOLVED SOLIDS → higher density

- Continental waters: dissolved solids < 1 g/L
- Exceptions: mineral waters, salt lakes, deep water of lakes
- Chemical density differences in lakes result in stable stratification

Table 7 — Salt content and density of water

<table>
<thead>
<tr>
<th>Salt content in %</th>
<th>Wt of unit vol. (kg/l) 4°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00000</td>
</tr>
<tr>
<td>1</td>
<td>1.00085</td>
</tr>
<tr>
<td>2</td>
<td>1.00169</td>
</tr>
<tr>
<td>3</td>
<td>1.00251</td>
</tr>
<tr>
<td>14</td>
<td>1.00818</td>
</tr>
<tr>
<td>35 (sea-water)</td>
<td>1.02822</td>
</tr>
</tbody>
</table>

Dead Sea
TEMPERATURE DIFFERENCES also influence water density

- At 1 atm (1013 hPa) highest density of water at 4 °C

- Colder and warmer water are lighter: have a distinct buoyancy relative to water at 4°C (sea level rise ~ climate change !!)

- Density differences increase with increasing temperature = important for stability of thermally stratified water bodies
The transition from liquid to solid at 0°C makes ice about 8.5% lighter than water and consequently it floats on the surface.

These drops represent 1 cm³ of water. The numbers show the mass in grams of this water related to the temperature scale above.

Warm water is less dense than cold water and hence rises above it.

Water is most dense at 3.94°C.

The effect of temperature on the density of water (pure water at a pressure equivalent to that at sea level.)
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Hydrological cycle
Precipitation

- rain
- hail
- flooding
- snow
Infiltration

Impermeable surface → no infiltration
Sources
Surface flow

Zwalm river (Belgium)

- 22 km long
- $Q = 1 \, \text{m}^3 \, \text{per second}$

Amazone river in Brazil

- > 6500 km long
- $Q = 250,000 \, \text{m}^3 \, \text{per second}$
Evaporation and transpiration
Condensation
Water balance – example of a lake

Change in stored volume over time \( \frac{dV}{dt} = \)

+ Inflow rate \( Q_i \) (m\(^3\)/day)
+ Catchment runoff \( Q_c \) (m\(^3\)/day)
+ Precipitation \( A \times P \) (m\(^2\) x m/day) \( \rightarrow A = \) surface area (m\(^2\))

- Outflow rate \( Q_o \) (m\(^3\)/day)
- Evapotranspiration \( A \times ET \) (m\(^2\) x m/day)

\( \pm \) Infiltration \( A \times I \) (m\(^2\) x m/day)
Water balance – example of a lake in Australia

Water Cycle Report
(All volumes in ML)

201,205,000
Evapotranspiration

Rainfall
205,205,000

Snow
11,855

Surface water

Change in major storages

Change in minor storages

Groundwater
3,369,016
ET from irrigated land ET
200,000
ET from irrigated land ET

Surface water diversions
11,855

Groundwater extractions to the economy
554,344

Rainfall / Runoff
599,507

Outflow (SW)

Unsaturated zone

Seepage from irrigation
200,000

Aquifer recharge (seepage)
200,000

Inflow from aquifers outside of entity
300,000

Aquifer flow out of entity

Lake Eyre Combined Water Management Area
Period reported:
01 July 2004 – 30 June 2005
Area: 1,160,635 km²
Water Balance Error: 0%

NB: Please note volumes for some items could not be provided. For further detail, see water balance report.
<table>
<thead>
<tr>
<th>Marine waters</th>
<th>Brackish waters</th>
<th>Inland waters</th>
</tr>
</thead>
<tbody>
<tr>
<td>oceans</td>
<td>estuaries</td>
<td>lakes</td>
</tr>
<tr>
<td>seas</td>
<td>creeks</td>
<td>ponds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>rivers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>brooks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>...</td>
</tr>
</tbody>
</table>
Marine waters

- Nearly 71% of the earth's surface is covered by oceans
- Largest part of marine waters is situated in southern hemisphere
- Salinity in the range of 30-38‰
Brackish waters

- Salinity in the range of 0.5 - 30 ‰.
- Most often occurs as the result of mixing of seawater and freshwater, like in estuaries.
- Example above = river Scheldt estuary in Belgium/The Netherlands.
Brackish waters

Example: varying salinity (expressed as g Cl⁻ per liter) in the Scheldt river estuary (Belgium and The Netherlands)
Inland waters

Aboveground ↔ Underground

Stagnant ↔ Running

Natural ↔ Artificial
Inland waters

Aboveground river

Underground river
Two horseshoe lakes along the Peruvian river Huallaga show how strongly this tributary of the Amazon meandered before the water cut off the bends (with now stagnant water).
Artificial Inland waters

- English gravel pits
- Roosevelt Dam in Arizona
- Suez canal
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Water resources on earth

Total water resources

Fresh-water reserves

Oceans 96.5%

Fresh-water Reserves 2.53%

Other 0.97%

Permafrost 0.97%

Rivers, Lakes, Swamps and other 0.34%

Ground water 30.1%

Glaciers and permanent snow cover 68.70%

Total water and freshwater reserves on earth
(World Resources Institute, 1994-1995).
## Water resources on earth

### Table 1 — Distribution of water in the hydrosphere (from Lvovitch, 1979)

<table>
<thead>
<tr>
<th></th>
<th>Volume (km$^3 \times 10^3$)</th>
<th>Percentage of total vol.</th>
<th>Per cent of Replacement fresh watertime (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans</td>
<td>1370323</td>
<td>93.94180</td>
<td>3000</td>
</tr>
<tr>
<td>Deep groundwater</td>
<td>60000</td>
<td>4.11320</td>
<td>5000</td>
</tr>
<tr>
<td>Active groundwater</td>
<td>4000</td>
<td>0.27400</td>
<td>14.094</td>
</tr>
<tr>
<td>Ice</td>
<td>24000</td>
<td>1.64500</td>
<td>84.566</td>
</tr>
<tr>
<td>Lakes</td>
<td>280</td>
<td>0.01900</td>
<td>0.987</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>85</td>
<td>0.00580</td>
<td>0.299</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>14</td>
<td>0.00096</td>
<td>0.049</td>
</tr>
<tr>
<td>Rivers</td>
<td>1.2</td>
<td>0.00008</td>
<td>0.004</td>
</tr>
<tr>
<td>Freshwater total</td>
<td>28380.2</td>
<td>1.92000</td>
<td></td>
</tr>
<tr>
<td>Water, Grand total</td>
<td>1458703</td>
<td>99.99984</td>
<td>99.999</td>
</tr>
</tbody>
</table>

UNESCO-IHE
Institute for Water Education
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Light and depth

The EUPHOTIC ZONE extends from the surface down to the 1% level.

The penetration of lake water by light.
(2) Subdivisions and communities in lakes

Pelagic zone = free water

- Organisms swimming (only occasional contact with bottom)
- Vertically divided into:
  1. Epipelagic / euphotic zone = upper layer, with light
  2. Bathypelagic / aphotic zone = deep water, no light

Benthic zone = bottom zone

- Organisms in or on sediment or on surface of plants
- Vertically divided into:
  1. Littoral zone = bank, with light
  2. Profundal zone = deep water, without light
Living organisms in natural waters

Fig. 17 — Subdivision of the lake habitat (from Reid, 1961).
Characteristic communities of the Pelagic zone (Table 2)

**Plankton** = floating organisms

→ Self-sustained motion insignificant in comparison with movement of water → dragged by water current

**Nekton** = fish, shrimps, amphibians, reptiles

→ Capable of self-sustained forward motion unassisted by water currents

**Periphyton** = organisms living attached to hard substrate

*E.g. algae, ciliates, bacteria*
Phytoplankton

Shows “primary production” = “photosynthesis” (see Course 2.5.)

Size: microscopic (µm range)
Zooplankton
(generally feeds on phytoplankton)

- ciliates
- rotifers
- cladocera
- “Water flea”
- copepods
NEKTON (= fish, shrimps, …)

(1) Plankton consumers
e.g. *Coregonus* (salmonids)

(2) Predatory fish
e.g. lake trout *Salmo trutta lacustris*
Algae adhering to a plant stem form a thick 'slime'.

Mostly green plus blue-green algae, diatoms and single-celled animals

PERIPHYTON
Aquatic animals in flowing waters

**Macroinvertebrates** *(are used as a way to assess water quality; see Course 3)*

Turbellaria, Amphipods, Midges, Diptera, Mayflies, Stoneflies, Caddisflies, Beetles